NOVA/BEAMLET/NIF UPDATES APRIL–JUNE 1997

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Nova Operations

Nova Operations performed 258 full system shots, resulting in 289 experiments during this quarter. These experiments supported efforts in ICF, defense sciences, university collaborations, laser sciences, and Nova facility maintenance. The shot rate was significantly above average this quarter, primarily due to increased reliability as a result of added maintenance time in January. Nova Operations was able to maintain a high shot rate while lending personnel to Beamlet and National Ignition Facility (NIF) to assist in the completion of project milestones.

Installation of the hardware required for "beam phasing" on Nova was completed in preparation for the initial experiments in early July. Beam phasing will provide the capability to irradiate indirectly driven Nova targets with two rings of beam spots on each side for studies of time-dependent second-Legendre and time-integrated fourth-Legendre flux asymmetry control. The timing and pulse shape of the outer rings of beams illuminating the targets will be controlled independently from those of the inner rings. This is achieved by propagating the pulse from the backlighter pulse shaping system down one spatial half of each beamline, while propagating the main pulse shape down the other half. When slightly defocused on target, the beam halves make two separate rings of spots on each side of the target.

The Petawatt project successfully completed the first two series of shots onto targets in the new Petawatt target chamber during this quarter. These shots placed up to 520 J of light on target in 5–20-ps pulses with a focal spot diameter of approximately 14 μm FWHM (for the Fast Ignitor project). Diagnostics on the Petawatt target chamber worked well. The sources of hot electrons and their heating effects were explored with x-ray spectroscopic and neutron production measurements. The peak irradiance achieved during these shots was about 10^{19} W/cm^2. Peak irradiances of up to an order of magnitude higher are expected in the next quarter with pulses as short as 500 fs.

Two significant target diagnostic capabilities for experiments in the ten-beam chamber were added this quarter. The 4ω probe beam was successfully tested and implemented on target shots. Also, the capability to delay beamlines 7 and 8 for up to 100 ns for x-ray backlighting of targets was added and successfully used.

Beamlet Operations

Beamlet completed a total of 61 system shots during 33 shot-days this quarter, with experiments on 1D beam smoothing by spectral dispersion (1D-SSD), spatial filter pressure tests, and pinhole closure. These experiments are all directed towards resolving scientific and engineering issues for the NIF. In addition, a number of system upgrades were completed. The highlights of these experiments are as follows:

- Concluded the 1D-SSD campaign that began in the second quarter of FY 1997. We reached 70% of the NIF red-line B-Integral with 1D-SSD, observing no unexpected effects. The experiments were concluded at this level to limit the fluence within the laser cavity until improved spatial filter lenses could be installed.
- Performed measurements on the allowable spatial filter background pressure for NIF. The Beamlet beam was resized to the correct *f*/# to simulate both the NIF cavity and transport filters.
- Made detailed pinhole closure measurements for various types of pinholes, including the standard "washer" type, offset leaf, and cone pinholes. This was done using time-resolved diagnostics, including a streaked pinhole interferometer and a gated optical near-field imager.

- Activated the NIF prototype wavefront controller, using the same hardware and software used in the second quarter for the large deformable mirror tests.
- Mounted a major engineering effort to conclude the final optics "Test Mule" installation. Initial thermal tests were completed with the Test Mule at vacuum.

Early in the quarter, we completed 6 shots on 1D-SSD at high power, using 200-ps and 1-ns pulses. B-Integral effects during SSD operation were not observed to be a problem, although we only reached 70% of the NIF red-line fluence, which is below where we expect to see major problems. The testing was concluded to avoid damaging the temporary lenses on the system, which were installed until we could obtain the replacement high-damage lenses.

In April, we installed the upgraded NIF deformable mirror controller in place of the original one that was on Beamlet since initial activation. The new system has advantages in maintenance and reliability and gives the NIF design engineers experience with the controller on a NIF prototypical system (i.e., Beamlet).

We performed 25 shots investigating effects of spatial filter pressure on output beam quality. The purpose for this series was to set the requirements for background pressure in the NIF cavity and transport spatial filters. The experiments were performed by bleeding air into Beamlet's transport spatial filter to reach specified background pressures in the range from 10^{-5} Torr to 10^{-3} Torr. At each pressure we fired a series of square 1-ns shots at increasing energy and determined beam perturbation by inspecting the output near-field beam profile. Simulating the NIF cavity spatial filter was simple; it has nearly the same *f*/# as Beamlet. However, to perform experiments relevant to the NIF transport cavity, we inserted a special beam apodizer in the front-end to shrink the beam to an effective *f*/80 on Beamlet. Beam breakup threshold for the NIF cavity and transport were measured at 6 mTorr and 2 mTorr, respectively.

Following the background pressure tests, Beamlet performed an 18-shot series on pinhole closure and backscatter. The goals for this pinhole series were as follows:

1. Determine the pinhole loading.
2. Measure closure time and phase shift at closure for the offset leaf pinhole.
3. Perform initial experiments on cone type pinholes.
4. Compare planar, offset-leaf, and cone pinholes with regard to back reflections.

Offset-leaf pinholes are a longitudinal dispersed variant of a square pinhole, where the four sides are offset to prevent plasma interaction between each of the sides. They were tested in both the square and diamond orientations using Ta blades. The ±150-µrad square oriented pinhole remained open for a 0.3-TW, square, 20-ns pulse, but closed at ~18 ns into a 0.43-TW pulse. The ±100-µrad, square-oriented offset-leaf closed at 10 ns during a 0.05-TW pulse, while the same pinhole, diamond oriented, remained open for 20 ns at 0.10 TW.

The most promising pinhole is the cone pinhole, which has a cone angle of about twice the converging beam. The ±100-µrad cone pinhole stayed open for 20 ns at 0.14 TW, although it closed when the power was increased to 0.17 TW. The NIF foot pulse is between 0.14 and 0.17 TW. A dramatic advantage of the cone pinhole is its near-total lack of back reflection, as discussed further below.

The pinhole backscatter experiments were performed with the following goals:

1. Determine the source of back reflections.
2. Compare the different pinhole geometries for backscatter performance.

Previous data suggested that the source of back reflection was the pinhole edges, especially if the final pinhole edges could be imaged back through the cavity pinholes. For diagnostic purposes, the pinhole plane was imaged in the west cavity diagnostics, and we clearly observed pinhole edge back reflection. The cone pinholes suppressed this by more than a factor of 10. Back-reflected energy from the cone remained insignificant at 3.5 TW, the highest power tested, which is a great advantage to injection mirror longevity. However, we did observe a large back reflection from the on-axis region of the pinhole for minor postpulses, underscoring the importance of controlling postpulses on the NIF.

May through mid-June was an intense period of activity to complete the "Test Mule," in which we will test NIF prototype final optics to high fluence and determine cleanliness requirements. The Mule consists of a temperature- and cleanliness-controlled vacuum chamber with a large access door and internal optical table for supporting the integrated optics module and final optics cell. While the chamber was put in place in April, a significant amount of work was required to install thermal controls, vacuum systems, and clean rooms. This was completed in June, and the system was successfully pumped down with window installed. Initial tests were performed on thermal performance, including direct and infrared camera measurement of the vacuum window temperature. The final week of June was spent on focal plane diagnostic alignment. We plan to install the final optics in early July, closely followed by system shots.

National Ignition Facility

During the third quarter of FY 1997, the NIF Project began its transition from strictly design to the initiation of conventional facility site work, the start of special equipment procurement, and the start of vendor facilitization in optics. Site preparation work began in April and will be completed in July, and the site excavation contractor was mobilized in June. The selection of the contractor for the target chamber was nearly completed, and will be awarded in July. The contract for the amplifier slab fabrication facilitization was awarded to Zygo Corp. in May.

There were no Level 0,1,2,3 milestones due during the third quarter. There were twelve Department of Energy / Oakland Office (DOE / OAK) Performance Measurement Milestones due; ten were completed within the quarter; and the other two (target area building shell, 100% design submittal, and optical design mid-Title II 65% review) have been completed as of the writing of this report.

The *NIF Project Execution Plan* (PEP) was updated, and the draft, including the updated project data sheet, is now being reviewed by DOE. The PEP is now consistent with the Level 0 Baseline Change Control Board (Secretary of Energy) action of January 1997, and with the detailed Project rebaseline prepared during the second quarter of FY 1997.

The major event for the third quarter was the Ground Breaking Ceremony, led by the Secretary of Energy and attended by approximately 2000 interested individuals, including distinguished members of Congress, the Department of Energy, the Department of Defense, the scientific community, the University of California, LLNL management, the Mayor of Livermore, national ICF Program managers, NIF Project personnel and their family members, and members of nongovernmental organizations.

The key assurance activities for the third quarter—to resolve the *Fire Hazards Analysis* recommendations, conduct the *Preliminary Safety Analysis Report* audit, conduct contractor audits, and oversee construction safety—are on schedule. Work on permits and National Environmental Policy Act determinations for soil reuse, along with the monitoring of the *Mitigation Action Plan* commitments, continues. As a special assignment, NIF Assurances supported DOE / HQ on the litigation of the *Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*.

Site and Conventional Facilities

Progress to date is satisfactory on Title II design and bid and construction activities for Construction Subcontract Packages (CSPs) 1 through 4. Title II Conventional Facility design is critical path, driven by conventional facility construction package bid and award schedules, and special equipment technical performance requirements as described in interface control documents.

Construction is proceeding on schedule and within budget. The site preparation contractor will complete in July, and the excavation contractor is mobilized on-site and working. Implementation of the Owner Controlled Insurance Program has proceeded successfully on schedule, in budget, and to the performance standards established for this service.

Laser and Target Area Building (LTAB) Design. The following activities were completed during the quarter:

- Delivered CSP-3 (Target Building Mat and Laser Bay Foundations) and CSP-4 (Laser Building Shell) bid documents to Procurement.
- Completed Title II 65% design review for CSP-6 (Target Area Building Shell) and Title II 65% design review for CSP-9 (Laser Building Buildout, Site and Central Plant).
- Received Title II 100% design documents for CSP-9.

Optics Assembly Building Design. The Project completed Title II 100% design review for CSP-5.1 (Optics Assembly Building).

Construction Packages. There are many construction packages in various stages of completion as of this quarter:

- Construction on CSP-1 (Site Preparation) is currently 90% complete and planned to complete on schedule in July.
- Parking lots associated with the work were turned over on schedule to allow completion of the fencing of the construction site as planned.
- The contract for CSP-2 (Site Excavation) was bid and awarded this quarter, and the Notice to Proceed given on May 28.
- The excavation contractor mobilized on-site on June 19, and that work is currently 5% complete.
- The Invitation for Bid packages for CSP-3 (Target Building Mat and Laser Bay Foundations) and CSP-4 (Laser Building Shell) were issued.
- Two addenda have been issued for CSP-3, and bids are due late in July.
- CSP-4 bids are due early in August.

Special Equipment

The third quarter included much activity in the special equipment area.

Optical Pulse Generation. Commercially produced fiber amplifiers were received and characterized during this quarter. After some modifications by LLNL scientists, the commercial units demonstrated the critical NIF performance characteristics. Major procurements were placed for the prototype preamplifier module, including laser diodes, power electronics, and most commercial off-the-shelf hardware. An updated multipass amplifier cavity design was operated successfully with single-pass gain in excess of 25, exceeding the NIF requirements.

Amplifier. Dramatic progress was made during this quarter on the amplifier prototype laboratory activation. Preliminary tests were completed to assess the cleanliness performance of the NIF bottom-loading concept for the first time, using full-scale hardware and flashlamp light exposure. The results are very promising and indicate that there are no fundamental flaws in the amplifier installation and maintenance strategy. In addition, the first gain measurements were completed on the prototype amplifier in an effort to activate the large-area diagnostic system.

Pockels Cell. The 2 × 1 plasma electrode Pockels cell prototype was activated during this quarter, and its performance exceeded NIF requirements. The use of external currents to improve the plasma uniformity was demonstrated, and found to be crucial to meeting the NIF switching efficiency requirements. This system of "plasma spreading" is now being incorporated into the NIF baseline design. Drawings were completed and hardware ordered for the 4 × 1 mechanical and physics prototypes. The mechanical prototype will be used for testing maintenance strategies, kinematic mounting and alignment techniques, as well as transport interfaces.

Power Conditioning. Initial tests were completed during this quarter to validate the 500-kA switch (ST-300 from Primex Physics International). Four switches were tested, each with slight modifications to the design, in order to identify performance sensitivity. The results were quite positive: the switch appears to survive 1000 to 2000 shots at full power before requiring refurbishment, and no prefires were experienced other than those induced to gather safety factor data. A second switch design, from a different manufacturer, was also tested for 2500 shots at NIF operating conditions. The switch performed flawlessly, and inspection indicates that its lifetime might exceed 10,000 shots. Other design progress included a preliminary design of a solid-state trigger generator for the switch, which was also prototyped and operated successfully. The strategy for grounding the amplifier support structure to provide good bonding during a failure of the amplifier frame assembly unit insulation was investigated. Initial designs of this bonding system required increasing the mesh frequency in the LTAB slab to reduce the inductance of the system. Recent analysis indicates that enclosing the cables in the cable tray would have better performance than an improved slab ground grid. Therefore, a change to the LTAB design to increase the grounding mesh density in the slab is not likely to be required.

Beam Transport Systems. Mid-Title II (65%) design was formally reviewed by an independent team of engineers from within and outside the NIF project. All four subsystems were presented in separate sessions, and action items were recorded. No issues were identified that would result in a delay of Title II design activities. A postreview effort was initiated to aggressively pursue all remaining interfaces to facilitate the completion of Title II. The long-lead procurement of stainless steel for spatial filter vacuum vessels was initiated with the on-schedule release of the first Request for Proposal. A recent engineering change to improve target irradiation symmetry during shots with subsets of beams has been incorporated into structural details without affecting the design schedule; the change affected the location of switchyard mirrors.

Integrated Computer Controls System (ICCS). There has been excellent progress in Title II design of the ICCS. The first of the Mid-Title II (65%) reviews, the supervisory software frameworks 65% design review, was completed in June and featured results obtained from the prototype. The review covered the development process, the object-oriented architecture, important CORBA test results, and the simulation program plan. Review documentation featured the first releases of seven (of about 30) software design descriptions to be prepared for the project. The next iteration of the software will incorporate database functionality and advanced error detection and recovery. Comments from the review team are pending. An overview document called the *Integrated Computer Control System Architectural Overview* (NIF-0002479) was prepared to assist the 65% review team in understanding the model-driven approach used in the ICCS. Sections of the document introduce the layered control system model, NIF software applications, computer and network hardware infrastructure, common object request broker architecture distribution, software development tools and environment, the abstract supervisory software framework, and software deployment. This overview document will be published on the LLNL-intranet and updated periodically to incorporate the latest summary information.

Integrated Timing System. The Two-Way Time Transfer Demonstration System has undergone environmental testing and a manufacturer-supplied upgrade while at Jet Propulsion Laboratory. The temperature effects on both transmission path length and terminal equipment were characterized. Upgrades addressing the long-term stability are planned for next quarter. In support of Local Timing Distribution development, measurements were made to characterize commercial delay generators operating in a clock-synchronous trigger mode. Results were excellent, with jitters less than 10 ps RMS and 15-hr stability of 20 ps RMS. The system will be delivered to LLNL in early July for continued development and testing.

Mirror Mounts. Testing continued this quarter to determine the mounting details for switchyard and target area mirrors that need to be supported from the backside. The specifications and cost of designs that are robust enough to withstand the target-backscattered UV light are being investigated.

Optical System Modeling. A detailed optical model (using commercial lens design software) has been completed. The model is wholly consistent with the optical configuration and includes the capability to simulate the alignment system operation. The model allows verification of such things as clear apertures, end-to-end wavefront error, and installation sensitivities.

Laser System Ghost Analysis. A nonsequential ray trace model for the main laser system with spatial filter beam tubes and vessel walls has been constructed. This model was used to calculate the ghost-reflection beam fluences inside the spatial filter beam tubes and to determine the locations of baffles and absorbers. The spatial filter vessel design is very compatible with the stray light management approach.

Final Optics Assembly. An engineering change request was approved in May for the final optics configuration. This changes the focal length of the focus lens from 7 m to 7.7 m, which enables the mechanical design to accommodate a line-replaceable unit (LRU) for a single beamline instead of an entire quad (four beams). This will greatly improve maintenance and cleanliness of the LRU. In addition, a contract for a prototype integrated optics module (IOM) was awarded. The IOM is the LRU for final optics, and includes a vacuum housing, vacuum window mount, and the interface to the beam tube and the water-based thermal control system. Initially this hardware will allow for testing of the pumpdown and evacuation concept as well as the thermal stabilization system. Follow-on testing will include integration of this hardware with the final optics cell and its actuation system.

Target Chamber Review. A portion of the Mid-Title II (65%) Design Review for the target chamber will be held on July 10, 1997. This review covers the design for the aluminum chamber so that it can proceed to fabrication. The 65% review for the remaining portions of the target chamber task (e.g., the first wall and the beam dumps) is scheduled for November 1997.

Target Chamber Procurement. During this period, the target chamber proposals were received from four companies. The proposals were reviewed by a technical evaluation team. Two vendors were selected for negotiations, and a final selection was made. A contract was placed with Pitt-Des Moines, Inc., in early July.

Neutron Spectrometer. An engineering change request for the neutron spectrometer (NS) was accepted by the Level 4 (Engineering) Change Control Board. This request added to the project construction all portions of the NS (cone) that are interior to the switchyard and target bay area, and that portion of the construction exterior to the building that is needed to not preclude the construction of the external portion of the NS. This was accomplished with no increase in cost and no impact to the schedule. A much simpler design for the interior and exterior portions of the NS was developed and was the driving factor in accomplishing the request.

Data Acquisition System. The layout of cable trays and penetrations in the shield wall and floors for the Data Acquisition System is proceeding. Penetration information for present and future diagnostics has been included in the penetration spread sheets and turned in to the architect/engineers (Parsons). The classification report by Parsons' consultant was reviewed, and comments were returned. Details on the security interface control document are being worked out with the appropriate people at Parsons. A preliminary schedule from the British Atomic Weapons Establishment has been received; they are generating a detailed schedule for the diagnostic manipulator. Work has continued toward finishing the target area portion of the *NIF Grounding and Shielding Plan.*

Start-Up Activities

Beam Symmetry. An engineering change was proposed by the Start-up team and approved by the Level 4 (Engineering) Change Control Board. It modifies the arrangement of a few beam tubes and mirrors in the switchyards and target area. This will allow maximum flexibility in the use of subsets of laser beams during initial NIF testing and long-term facility operations by users, thus permitting the increase of shot rate on target with beam subsets while maintaining symmetrical irradiation.

Operability Model. A status review of the operability model, a discrete-event simulation model, was held during May. Initial estimates of LRU random failure rates and scheduled maintenance requirements are provided as inputs to the simulation. Using these estimates, preliminary simulation results from the Operability Model address two facility issues: (1) estimation of the operations staff that correlates to the maintenance rates and (2) assessment of shot availability versus staffing. During Title II, the model will incorporate updated information on reliability, availability, and maintainability; updated timeline information; identification of types of people for each task; and more detailed characterization of failures and their impact on the shot cycle.

Operating Procedures. A draft *Procedure for Writing NIF Operating Procedures and Training Documents* has been prepared and is being reviewed by start-up personnel. The document outlines a proposed process for developing written operations procedures and training qualification documents for NIF. It includes a description of the approach chosen, a plan for implementation, and estimates of time and resources required. Examples of document templates, titles, and contents are given. Operations personnel at Lawrence Berkeley National Laboratory and Stanford Linear Accelerator Center were consulted during preparation of this draft.

Optics Technology

Optics Vendor Facilitization. The schedule for bidding and negotiating the optics facilitization contracts has been maintained with respect to the NIF schedule. Moore Tool Company was awarded a contract in June for the NIF crystal diamond turning. Negotiations for the fused silica facilitization contract began in June, and are expected to be completed in July. Negotiations for the mirrors, windows, and polarizers flats finishing and lens finishing contracts continued through June, and are expected to be completed in July. Work is continuing on the glass melting facility at Hoya, which is scheduled to be completed in October. Zygo Corp. was awarded the contract for amplifier slab finishing facilitization in May.

KDP Crystals. In the KDP rapid growth program, conditions have been identified in subscale tanks that produce the needed aspect ratio for NIF-size boules. The first test at full size will begin in July, with the results available in August. Rapid-growth KDP crystals grown from ultrapure material and continuous filtration at subscale yielded damage thresholds equivalent to the best Beamlet crystals, and above the NIF requirement. Continuous filtration has been added to a full-size tank; the run is scheduled to be complete in early August.

Optical Fabrication Development. The first of the Beamlet Mule focus lenses was produced in June, and damage tests at full aperture are scheduled for July. The second lens is still on schedule to be delivered in July. Initial damage tests of small, inspection-polished cerium-doped mirror substrates were encouraging. Subscale parts will be coated for damage testing in the first fiscal quarter of 1998. Full-size prototype mirrors from three U.S. sources were laser conditioned to the NIF fluence requirement for the transport mirrors. These mirrors will be installed in Beamlet in August.

Educational Outreach. LLNL signed an agreement with Monroe Community College in Rochester, New York, to begin a certificated optics fabrication program this Fall. This is expected to be a significant benefit to the NIF; it will provide trained workers that are needed in the optics fabrication businesses that supply components to the project.

Upcoming Major Activities

During the fourth quarter of FY 1997, the NIF Project will continue its transition from strictly design to the start of conventional facility site-work, special equipment procurement, and vendor facilitization in optics. Site excavation work will begin in August and will continue for several months. Also, the contracts for the start of building construction will be placed. In special equipment, several Mid-Title II (65%) design reviews will be held, and the contract for the target chamber will be placed, along with a contract for large stainless steel plates for the spatial filters. In optics, the contracts for the amplifier slab fabrication facilitization and for lens and window fabrication will be awarded.